ARCTIC CLIMATE OBSERVATIONS USING UNDERWATER SOUND (ACOUS)

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LONG TERM GOALS

The long term goal of the ACOUS Project is to provide synoptic year-round observations (of decadal scale) using acoustic thermometry, of Arctic and Northern Pacific Ocean temperature and Arctic ice cover, which could be influencing regional and global climate change. These measured data will then be assimilated into global climate models to improve their fidelity and predictive capabilities.

OBJECTIVES

The specific objectives of the ACOUS Project in FY 97-98 are the following:

- Design, build and deploy an acoustic receiving array in the Beaufort Sea off Pt. Barrow, Alaska, in the summer of 1998.
- Repair of the US-Canadian Spinnaker acoustic receive array in the Lincoln Sea in the spring of 1998.
- Support the design, construction and deployment of a Russian acoustic source off Franz Josef Land in the summer of 1998.
- Perform acoustic and oceanographic modeling, and data analysis and interpretation of data obtained under the ACOUS Project.
- Support design studies for a central Arctic acoustic source.
- Support the Joint US-Russian Coordination Working Group in Acoustic Thermometry of Ocean Climate.

APPROACH

The ACOUS Project is a bilateral program being executed jointly with the Russians under the auspices of the Science and Technology Committee of the Gore-Chernomyrdin Commission and in accordance with a Memorandum of Understanding signed in December 1994 by the US Secretary of Defense William Perry, the Russian Deputy Minister of Defense Andrei Kokoshin, and the Russian Minister of Science Boris Saltykov. ACOUS will use underwater acoustic remote sensing to measure changes in the ocean temperatrue, and the extent and thickness of the ice cover in the Arctic Ocean. ACOUS will provide data on the large thermohaline change now occurring in the Arctic Ocean, and advance the understanding of short and long-term variability in the Arctic Ocean and its relation to global climate trends. The following Russian organizations are involved in ACOUS Project:

Shirshov Institute of Oceanology, Moscow
Institute of Applied Physics, Nizhny Novgorod

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Institute of General Physics, Moscow
N.N. Andreyev Acoustics Institute, Moscow
Arctic and Antarctic Research Institute, St. Petersburg

ACCOMPLISHMENTS

In the three months that the project has been formally underway, the project organization has been established. Subcontracts have been executed or are in the process of being executed to support the project organization.

A trip was conducted to Alaska in September 1997. The primary purpose of the trip was to visit Barrow, Alaska, where the cable from the acoustic receive array off Pt. Barrow, Alaska, will be brought ashore. The officials of the North Slope Borough and the Barrow Arctic Science Consortium were briefed on the ACOUS Project, and contacts were established for the work to be accomplished at Barrow during the acoustic receive array installation. The trip was also conducted to meet the Arctic Ocean modeling group that will be supporting the ACOUS effort at the University of Alaska Fairbanks and to visit the law firm in Fairbanks, Alaska, that will be assisting with the permits and research that will be required to support the acoustic receive array installation off Pt. Barrow, Alaska, and the acoustic source installation off Franz Josef Land, Russia.

The fifth meeting of the US-Russian Coordination Working Group Meeting was held in New Orleans, Louisiana, in early October, hosted by the Naval Oceanography and Meteorology Command. The Working Group visited the Naval Oceanography and Meteorology facilities at Stennis Space Center, Bay St. Louis, Mississippi. The Working Group also reviewed and approved the Joint US-Russian Implementation Plan for 1997-1998.

The System Requirements have been completed for the acoustic receive array to be installed off Pt. Barrow, Alaska, in the summer of 1998. The Technical Requirements have been completed for the Russian acoustic source to be installed off Franz Josef Land in the summer of 1998. The detailed design of the acoustic receive array and the acoustic source are currently in progress.

SCIENTIFIC/TECHNICAL RESULTS

Research in the acoustical response to the Arctic Ocean circulation is being conducted by scientists at SAIC and the University of Alaska, Fairbanks (UAF). A two-dimensional model of the Arctic Ocean-Atmosphere system was run at UAF for a simulation period of 47 years. Two general regimes of circulation with a 15-year period were discovered. Anti-cyclonic circulation, resembling summer time conditions and cyclonic circulation, similar to winter time conditions. The circulation in these two regimes was studied using a wind-driven 3 dimensional circulation model. Four runs were calculated with the atmospheric conditions for spring and fall of 1987 (anti-cyclonic) and 1992 (cyclonic) used as boundary conditions. Sound speeds were computed along a path similar to that expected for the ACOUS experiment (Franz-Josef Land to Barrow). The salinity, temperature and sound speed as a function of range and depth are shown in figure 1. The range integrated differences relative to May 1987 are plotted in figure 2.

Broadband acoustic simulations were run using the sound speed fields created by the UAF model. The results for a 20 Hz signal with a 2 Hz bandwidth are shown in figure 3 for May 1987. The upper left panel is the acoustic arrival pattern received on a vertical array. The lower left is the average sound speed profile. The upper right panel shows the output of a mode filter, assuming a dense array. The lower right panel is a plot of the mode arrival statistics (mode

arrival time and energy). The difference in mode travel times for the three seasons relative to May 1987 is shown in figure 4. The cyclonic period (92) has later arrival times corresponding to cooler temperatures. The seasonal signal, as well as the inter-annual signal is visible. The largest acoustic signature is in mode 2, which corresponds to the changes in the Atlantic Water penetration into the arctic.

Future work involves running the 3 dimensional model at UAF for a 30 year period. This will permit the calculation of an acoustic time series which will lead to a better understanding of the observables. Acoustical modeling work is being done on the validity of adiabatic mode theory calculations downslope and across the Lamontosov ridge.

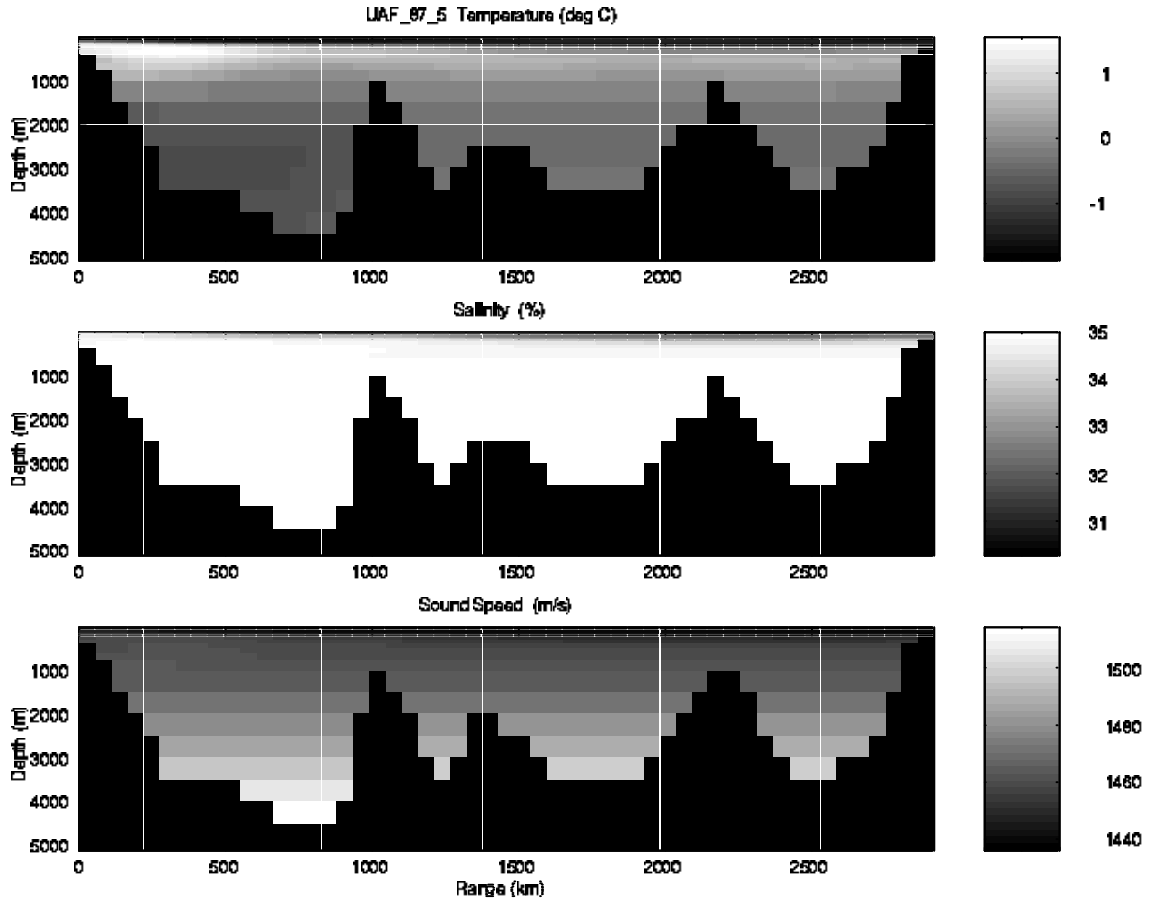

Figure 1

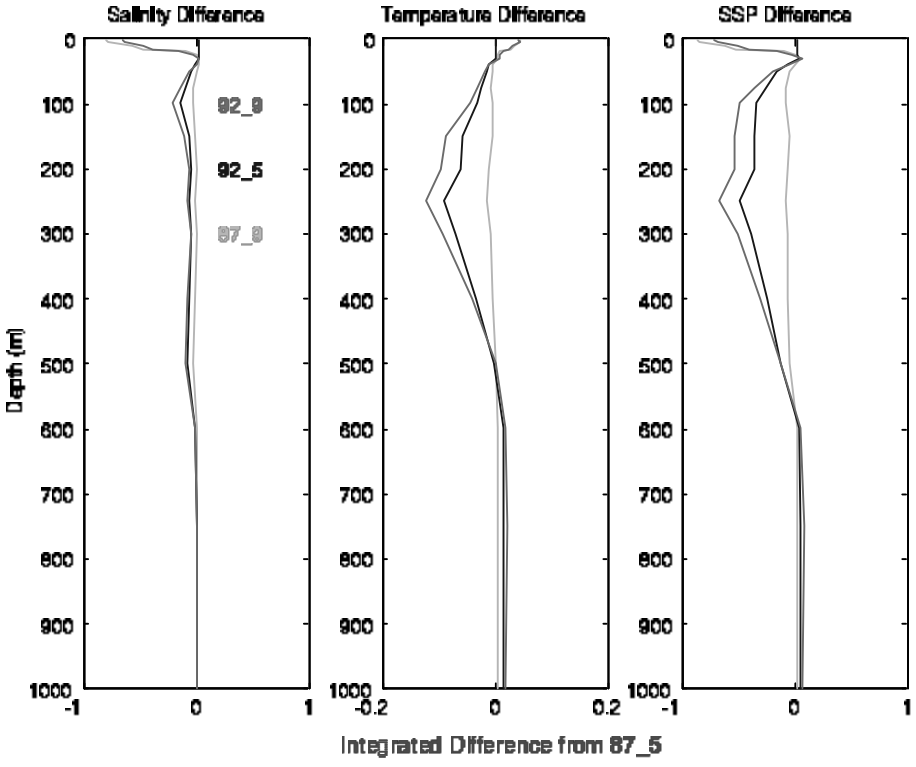

Figure 2

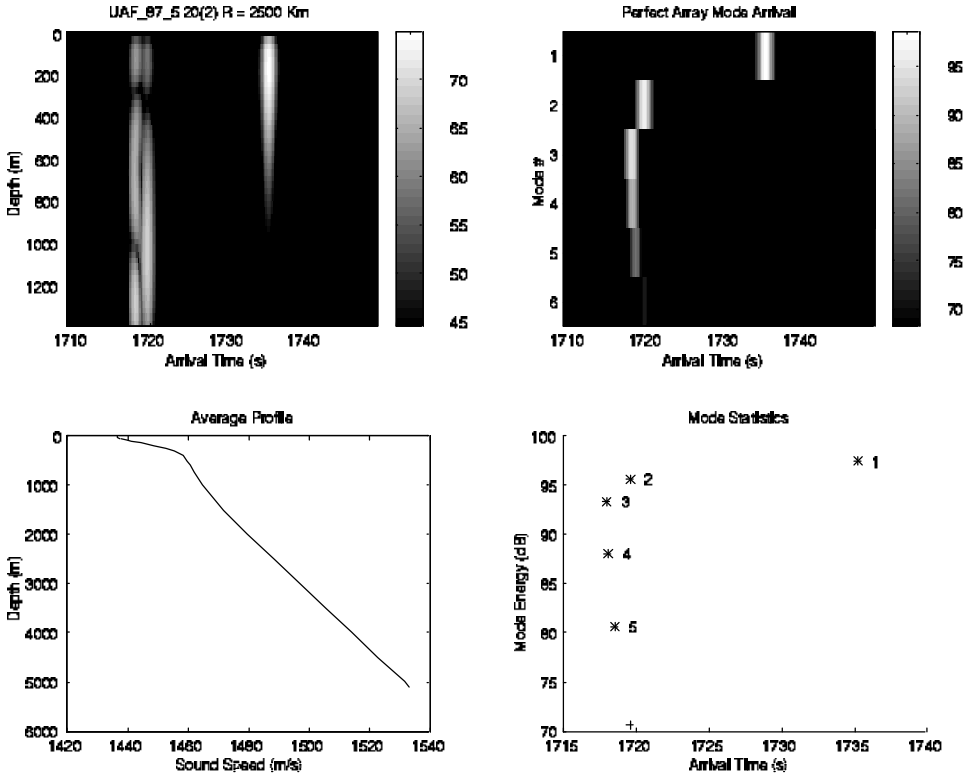

Figure 3

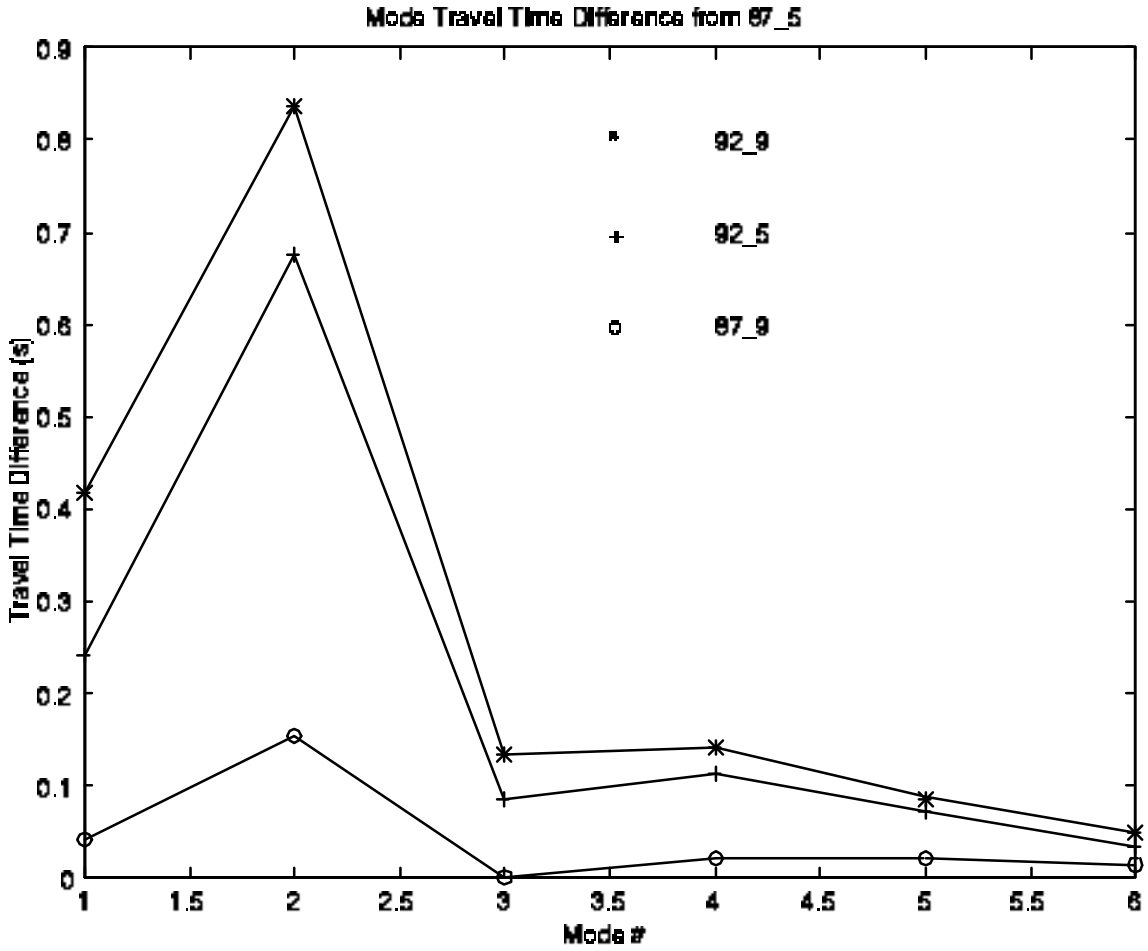

Figure 4

IMPACT FOR SCIENCE APPLICATIONS

- Long Range Acoustic Propagation code to support Dr. Jeff Simmen, Ocean Acoustics, ONR Code 407-9, in understanding long range propagation and the effects of internal waves (expected to be very small) and ice scattering in the Arctic.
- Shallow Water bottom interacting acoustics including mode coupling effects as a consequence of the modeling and data analysis of the Franz Josef Land to Lincoln Sea acoustic path, also to support Dr. Jeff Simmen, Ocean Acoustics, ONR Code 407-9.
- Low Frequency acoustic source technology to support Sensors, Sources, and Arrays, ONR Code 428-11, and CNO OP N87 (Mr. John Schuster) in further understanding Russian electrodynamic source technology for possible US Navy applications.
- Understanding the Arctic climate system and Arctic Ocean circulation, important for all U.S. Navy operations in the Arctic Region.

TRANSITIONS

Project started in July 1997. No transitions as yet.

RELATED PROJECTS

A closely related project is the "Arctic Research from Submarines" Project, also known as SCICEX. Since 1993, annual SCICEX cruises have provided a chance to coordinate Arctic oceanographic initiatives with acoustic thermometry sampling. To date, the SCICEX data has allowed us the opportunity to establish recent regional patterns of circulation and water mass variability. Using SCICEX measurements, we have verified that the acoustic arrival time structure measured during the Transarctic Acoustic Propagation Experiment (TAP) is consistent with data collected along a similar track during SCICEX-95. Measured SCICEX tracks have proven to be of immense value to the community of Arctic acousticians and physical oceanographers as they construct the three-dimensional distributions of heat, salt and dissolved oxygen in the central Arctic Ocean. SCICEX transarctic-sampling efforts have generally been planned to coordinate with previous and future planned acoustic transmissions. These temperature and salinity observations are necessary to baseline our acoustic thermometry sampling measurements planned for the ACOUS monitoring network. The SCICEX program allows for accurate local measurements of temperature, salinity and ice cover, whereas the ACOUS network will provide basin scale, all-season, synoptic measurements. Additionally, the ACOUS program needs to understand how water column anomalies might affect acoustic propagation travel time and mode coupling. High resolution SCICEX temperature and salinity measurements collected from these anomalous features will be studied in detail to determine potential acoustic consequences. We anticipate that water column measurements from SCICEX-98 will focus on continuing to track the interannual water column variations that have characterized the past decade, and provide an accurate baseline to calibrate the ACOUS acoustic receiver.

The efforts of ACOUS will also be coordinated with a new European program starting this year called Acoustic Monitoring of the Ocean Climate in the Arctic Ocean. This is being led by Ola Johannessen and includes the participation of the Nansen Environmental and Remote Sensing Center (NERSC) in Norway, the Scott Polar Research Institute in the UK, the Max Planch Institute for Meteorology in Germany, and the Nansen International Environmental and Remote Sensing Center in Russia.

PUBLICATIONS:

Mikhalevsky, P.N., A. Gavrilov, and A.B. Baggeroer, "Transarctic Acoustic Propagation Experiment and Climate Monitoring in the Arctic," Journal of the Acoustical Society of America, to be submitted December 1997.

Moustafa, M.S., P.N. Mikhalevsky, M. Steele, and T. Boyd, "Upper Arctic Ocean Hydrography Observed During SCICEX-95," Journal of Marine Research, to be submitted December 1997.

Gavrilov, A., P.N. Mikhalevsky, and M.Y. Andreyev, "Effects of Mode Coupling in Acoustic Thermometry of the Arctic Ocean," Journal of the Acoustical Society of America, submitted November 1997.

Mikhalevsky, P.N., "Acoustic Phase of Reflection from Sea Ice at Low Frequencies," in preparation for submission to Journal of the Acoustical Society of America.